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BULLETIN

OF THE

AMERICAN GEOGRAPHICAL SOCIETY.

Vol. XXXVII **1905.** **No. 4**

THE GORGES AND WATERFALLS OF CENTRAL NEW YORK.*

BY

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NUMBER AND VARIETY.—There are few, if any, regions in the United States where, in so small an area, so great a number and variety of falls and gorges are found as in the valleys near the heads of Cayuga and Seneca Lakes. Many of these are of such wildness and beauty that, near large centres of population, they would long since have won wide reputation and attracted the thousands. Falls in Europe, to which annual pilgrimages are made by streams of tourists, including many Americans, are excelled in beauty and

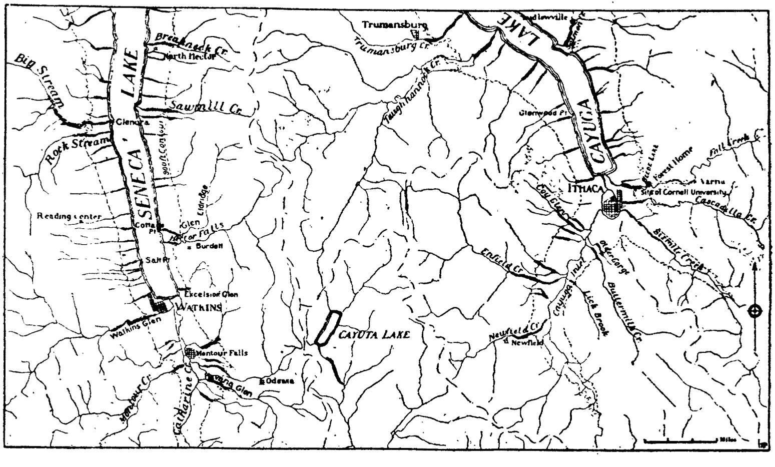

FIG. 1.—ITHACA, N. Y., AND SURROUNDINGS. THE BROAD PORTIONS OF THE STREAMS SHOW THE LOCATION OF SOME OF THE MORE IMPORTANT GORGES. 900-FOOT CONTOUR MARKED BY DOTTED LINE.

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* A brief abstract of this paper was presented before the International Geographic Congress at Washington in 1904.

interest by scores of falls in the central New York region, to which no names are yet given.

Among the many gorges or glens of this region only one, Watkins Glen, has attained wide reputation. To this glen tourists come in large numbers each summer; and a gorge nearby, Havana Glen, profits by the reputation of Watkins, and shares in the attention of these tourists. These two glens are beautiful, and it is well

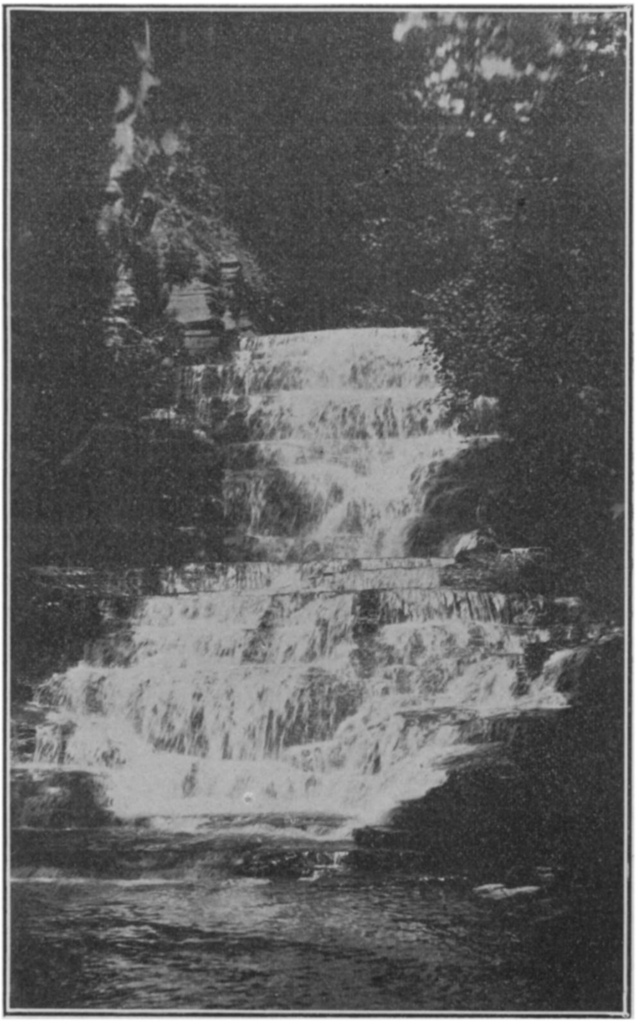

FIG. 2.—ONE OF THE NUMEROUS WATERFALLS, NEAR ITHACA, N. Y.
THIS IS A TYPICAL STEP-FALL.

worth one's while to make a long journey to see and enjoy the wild natural scenery which they contain. Yet they are only two of many, and those who know the region well will agree that others are at least their equal. Indeed, to the genuine lover of scenery many of the others have superior attraction, because the natural beauty is not marred by board sidewalks, ladders, and fantastic signs, such as Pluto's Fall, Bridal Chamber, etc., which the exploiters of the glens have deemed it necessary to hang in conspicuous places to arouse the interest of the horde. Nor are the less well-known glens infested with throngs of unsympathetic tourists and pleasure-seekers.

One who loves to wander about in the solitude of wild natural scenery, gaining every now and then a glimpse of a scene of rare beauty, and finding such scenes in quick succession and constant variety, could find employment for weeks, with each day full of interest and pleasure. He would return rested, refreshed, and inspired, and could easily bear away a record of the beauties of the region obtained by camera or by pencil.

The abundance of these gorges and falls in this locality has, of course, an explanation. This explanation is to be found partly in the peculiar physiographic history of the Finger Lake valleys, and partly in the rock structure, to which the details of gorge-form and waterfall outline are largely due. It is the purpose of this paper to consider both the general cause for the abundance of gorges and falls and the explanation for the more pronounced details of their topography. These considerations lead us along a number of different lines.

TOPOGRAPHY OF THE REGION.*—The Finger Lakes, of which Cayuga and Seneca are two, are situated in valleys in the dissected plateau of central New York. This plateau, which increases in ruggedness from north to south, is deeply cut by a network of valleys of mature form, the valley slopes, on the whole, being sufficiently moderate for farming, but with some slopes too steep for this, though tree-covered. Where not too steep the hill slopes are usually smooth and thinly veneered with glacial drift; but where crossed by morainic bands the drift-cover perceptibly thickens, and the minor details of topography become varied. Most of the valleys are deeply drift-filled, and often quite flat-bottomed.

Two of the main valleys of the plateau are occupied in part by Lakes Cayuga and Seneca; other similar valleys are partly occupied by the other Finger Lakes, Skaneateles, Owasco, Keuka, and Canandaigua. All these lakes drain northward, and outflow to the east-flowing Seneca River; and if there is any northward continuation of their valleys it is deeply buried beneath drift. The northern, or outlet, ends of the two largest lakes, Cayuga and Seneca, which extend in a general north-south direction, lie beyond the edge of the plateau on the Lake Shore plains, which extend from Lake Ontario southward to the northern escarpment of the plateau region. The southern, or inlet, ends are in the plateau, the hills on either side rising gradually to elevations of 1,600–2,000 feet above sea-level, or from 1 200 to 1,600 above the lake surfaces. The highest and most rugged part of the plateau is several miles south of the heads of the lakes. Along the northern edge of this most rugged portion is the divide between the Finger Lake drainage and that of the south-flowing Susquehanna. The divide of the Cayuga Valley is 14 miles south of the head of the lake; of the Seneca Valley 15 miles.

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* For another account of the topography of the region, and a bibliography of the literature on its physiography, see Tarr, Lake Cayuga a Rock Basin, *Bull. Geolog. Soc. Amer. V*, 1894, 339-356.

Each of the Finger Lakes occupies part of a valley which, in its general outline at least, is due to river erosion. The valleys are winding and, at first glance, seem in harmony with the rest of the topography, being merely longer and deeper than the tributary valleys. The length of Cayuga Lake is about 38 miles, and of Seneca 35 miles. Cayuga has a depth of 435 feet and Seneca 618 feet; but that the actual rock bottom is lower than this is indicated by the fact that a well-boring at Watkins, at the head of Seneca Lake, shows that the rock bottom is there fully 1,080 feet below the lake-level. These figures place the rock bottom of the Cayuga Valley at least 54 feet below sea-level, and of the Seneca Valley at least 637 feet below sea-level.

The lateral streams tributary to the Cayuga and Seneca troughs approach in broad, mature valleys to the very edge of the main valleys, and then end as hanging valleys* at an elevation of from 800 to 900 feet above sea-level, or 350 to 500 feet above the lake surface. In the Seneca Valley the bottoms of these hanging valleys are about 1,500 feet, and in the Cayuga Valley about 845 feet above the deepest-known point in the main valley. It is in descending from the edge of these hanging valleys to the lake valleys that the streams have cut the postglacial gorges which are so abundant. In addition to the postglacial gorge-cutting, there has been an earlier period of gorge-cutting antedating the time of deposit of the last glacial drift. These earlier gorges are broader, and hence required a longer period for formation than the postglacial gorges. That they are not postglacial is proved by the fact that they are more or less completely filled with morainic deposits. Where entered or crossed by the postglacial streams they introduce decided variety in the form and characteristics of the postglacial valleys.

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* Tarr, American Geologist, Vol. XXXIII, 1904, pp. 271-291.

THE BED ROCK.—The plateau in which the Finger Lakes lie is made of Devonian strata, mainly shales with sandy layers, increasing in abundance toward the top. There is every gradation from very friable shale to dense, fine-grained, well-cemented sandstone. The sandy beds are usually thin, and there are frequent and abrupt alternations from shale to sandstone. These alternations have an important influence on the form of the gorges and the outline of the waterfalls. The fact that the sandy layers increase toward the top of the series accounts, in part at least, for the greater elevation and ruggedness of the dissected plateau toward the south.

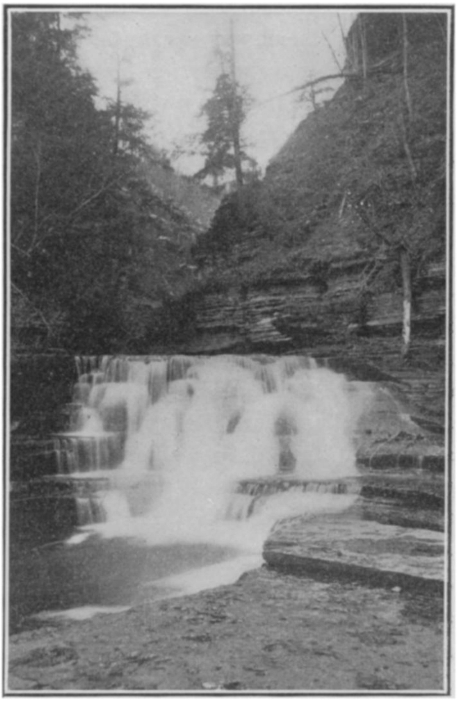

FIG. 3.—A FALL IN ENFIELD GLEN, NEAR ITHACA, N. Y., SHOWING THE INFLUENCE OF THE HORIZONTAL STRATA ON THE GORGE WALL AND WATERFALL OUTLINE.

Besides shale and sandstone there are, in the southern half of the lake valleys, two beds of limestone, only one of which, the Tully, is pronounced enough to produce an influence on the topography. This bed has a thickness along Cayuga Lake of about 15 feet, and, being a dense, massive layer in the midst of friable shales, resists denudation better than the surrounding strata.

All these strata are so nearly horizontal that, in considering their influence on topography, they may be classed as horizontal. However, the strata have a gentle southward dip, and they are slightly disturbed by a series of low folds, with approximately east-west axes; but these are too broad and low to have a pronounced effect on the topography. The main valleys of Lakes Cayuga and Seneca cross the folds almost at right angles. There are also some very small faults and a number of dikes, whose influence on topography is too imperceptible to call for consideration, excepting in connection with subordinate details. Both the folding and faulting increase southward, beyond the heads of Lakes Cayuga and Seneca, and toward the region of Appalachian folding, with which these disturbances are doubtless connected.

The entire series of strata is crossed by numerous well-developed, approximately vertical joint planes, meeting at very nearly right angles. They vary somewhat in direction, and decidedly in abundance and perfection of development. In places they occur at intervals of a few inches, but more often of several feet, and they are rarely entirely absent in an area of twenty or thirty square feet. Sometimes both series of joints are equally developed, but more commonly one set is better developed than the other. Where opened and exposed by weathering, as in gorges and along the lake-shore cliffs, the joint planes are seen to have variable extent, from short breaks of only a few inches to great planes of breakage, traceable, both vertically and horizontally, for scores of feet. Naturally, therefore, the joint planes exert a profound influence on the topography. This influence is clearly seen in the details of gorge-form and waterfall outline, as well as in stream outline; how much influence it may have had on the larger topographic features is not now clear.

GENERAL PHYSIOGRAPHICAL HISTORY.—The physiographical history of this region has been long and complex, and at present many of its phases are not understood. That the region has long been subjected to denudation is evident from the mature form of the valleys; but that this history has not been simple and uninterrupted is evident from many facts. Since the drainage history is not fully interpreted, and since much of it has only indirect bearing on the problems of this paper, no further consideration of the vague early history will now be undertaken.

Before the advent of the ice-sheet of the Glacial Period the sum total of the various drainage changes had produced a mature topography not greatly different, in general features, from that now found in the region. Stream-courses may have been different, and in some cases certainly were, and there have been many changes in the details of topography, including the formation of the post-glacial gorges. The advance of the ice-sheet, perhaps repeated more than once, caused modifications of the topography, the full extent of which is not now apparent. By ice-action valleys were deepened somewhat by erosion; others were shallowed by drift deposit; portions of pre-existing valleys were transformed to lakes; and streams were, in many instances, turned out of their valleys, and even turned over to other systems. But all these changes were minor when compared to the systematic and widely-extended development of mature topography which characterizes the region, and which was the result of a long period of development.

THE HANGING VALLEYS.—At some relatively recent period in the drainage history of the region the hanging tributary valleys joined the main Cayuga and Seneca Valleys at a level not far from that of the 800–900 foot contours.* This conclusion is based upon the established fact that a mature valley has a moderate grade or bottom slope. At present the tributary streams have the moderate grade of maturity nearly to the end of the hanging valleys, then abruptly change their grade, and tumble down the main valley sides in steeply sloping, narrow gorges.

Taking one stream as a type, this change will be readily understood. Fall Creek (Fig. 4) which forms the northern boundary of Cornell University campus, has an average grade of 20 feet a mile in the first 25 miles of its course. Just above the University the stream quickens, and from this point onward until it reaches the Ithaca delta, which it has helped build at the head of Lake Cayuga, it descends 475 feet in a distance of 1½ miles. Could the lake-waters and sediment-filling of this valley be removed, the stream would descend at least 845 feet in 2 miles. Other streams illustrate the same change in slope; and, in the case of those in the Seneca Valley, taking Watkins Glen as a type, if the tributary streams could be continued down to the rock-floor of the main valley, their descent would be 1,500 feet in 2 miles.

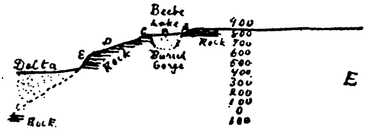

FIG. 4.—PROFILE OF FALL CREEK, WHICH DESCENDS THE CAYUCA VALLEY SLOPE ALONG THE NORTHERN BOUNDARY OF THE CORNELL UNIVERSITY CAMPUS. (VERTICAL SCALE EXAGGERATED ABOUT FIVE TIMES. COLUMN OF FIGURES GIVES ELEVATIONS IN FEET WITH REFERENCE TO SEA-LEVEL.)

These changes in slope are not due to the turning of streams out of their valleys, for there are no buried valleys to be correlated with these mature, upland, hanging tributary valleys. With the exception of small breaks where buried gorges descend to the main valleys, the rock-walls of the main valley sides can be traced continuously for miles along the 800–900 foot contours. Such a decided change in valley profile cannot be associated with the normal development of a mature valley. Therefore, some exceptional explanation must be sought, and this explanation must deal with causes which will account for the lowering of the main valley bottom below the level at which the hanging tributary valleys formerly entered the main valleys.

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*Tarr. Amer. Geol., Vol. XXXIII, 1904, pp. 271–291.

While there are several possible causes for the lowering of a valley bottom below the level of its tributaries, including block-faulting, only two seem possibly applicable to this region. One of these is ice erosion, deepening the main valley, but not affecting the tributaries, and therefore leaving the tributary valleys hanging above the bottom of the over-deepened main valleys. The other explanation is that some marked increase in the cutting power of the main streams, through uplift or other cause, permitted them to deepen their valleys rapidly, while the side valleys, occupied by weaker streams, were not deepened to such a degree. This new power given to the streams is called rejuvenation.

Ice erosion has been the current explanation of hanging valleys, and was applied to the Finger Lake region by Lincoln * as early as 1892, and by myself in 1894 †. Later studies, have, however, tended to discredit the glacial erosion hypothesis, and to give support to the rejuvenation hypothesis. This subject, and its application to the Finger Lake region, has been discussed in another paper ‡ in which it is shown that, while the evidence at hand is not sufficient to establish the rejuvenation hypothesis, it favors this rather than the explanation by ice erosion.

Whichever of the hypotheses the future discovery of evidence establishes will not alter the fact of main importance, from the standpoint of the present paper—namely, that over-deepening of the main Cayuga and Seneca Valleys has made it necessary for the tributary streams to descend by steep slopes over the walls of the over-deepened lake valleys, and in them to cut the gorges and form the waterfalls with which the region abounds. The fact that the gorge-cutting of the present cycle is postglacial has so limited the time available for valley-deepening that the streams, even where

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*Amer. Journ. Sci. Vol. XLIV, 1892, pp. 290–301.

†Bull. Geol. Soc. Amer. V, 1894, 339–356.

‡Tarr, Amer. Geologist, Vol. XXXIII, 1904, 271–291.

working in soft shale, and notwithstanding their great slope, have been able to cut only small gorges; and, not being able in this short time to establish a moderate grade, the stream-courses are consequently interrupted by a succession of waterfalls.

THE BURIED GORGES.—In all the valleys so far examined older gorges, more or less drift-filled, have been discovered. In some cases the drift-filling completely obscures the older gorges and causes the postglacial streams to follow an entirely different course to the main valley, but more frequently the buried gorges are revealed by the downcutting of the postglacial streams which cross and, in some cases, follow them for a distance. These gorges are steep-walled, like the postglacial gorges, but are decidedly broader, and hence required a much longer time for their formation. In time of origin they can be certainly placed somewhere between the period of development of the mature tributary valleys and the last ice advance.

For some reason, as yet uncertain, the streams had their power of downcutting increased after the mature valleys were developed, and the result was the cutting of this series of gorges in the bottoms of the mature valleys. As in the case of the over-deepening of the main valleys, there are two possible explanations for this increase in stream power, and the solution of the one problem will solve the other. If the main valleys have been over-deepened by ice erosion the gorges are evidently to be interpreted as the result of stream-cutting during interglacial time, when a new, lower base-level had been established by glacial erosion during an earlier ice advance. If the main valleys have been deepened by rejuvenation through uplift, the side valley gorges represent the measure of cutting which the weaker members of the system were able to perform while the main streams were lowering their valleys to the present depth.

The solution of this problem is not yet at hand; but the fact of importance to the present paper is established—that there is a system of older, partly-buried gorges which must be considered in any attempt to understand and interpret the features of the gorges and falls of central New York. The grade of these gorges is not known, since their bottoms are obscured by drift-filling.

THE POSTGLACIAL GORGES.—When the glacier disappeared, and drainage was re-established on the land which the ice had left, the water followed the lowest courses opened to it. Naturally, in the mature upland valleys the stream-courses were approximately along the lines of the preglacial drainage, though by drift deposits or other glacial interference, streams were often caused to depart from the exact direction or position of preglacial stream-flow. Rarely, in these upper portions of the larger streams, has the work of erosion removed the drift down to the bed-rock. The valley-bottom grade has not been steep enough for much stream-cutting, and at best the postglacial work has resulted in the erosion of young, narrow valleys in the drift.

Approaching the lower end of the hanging valleys the slope increases, the stream-flow quickens, and the gorge-cutting begins. Thence on to the main valley the tributary streams, large and small, flow almost, if not quite, continuously in postglacial rock gorges, which the streams are now busily cutting in the rock walls of the main valleys. For these reasons there is a decided change in the character of the lower and upper portions of nearly all the streams entering the southern end of the Cayuga and Seneca Valleys (Fig. 1); and this change occurs approximately at the edge of the hanging valleys.

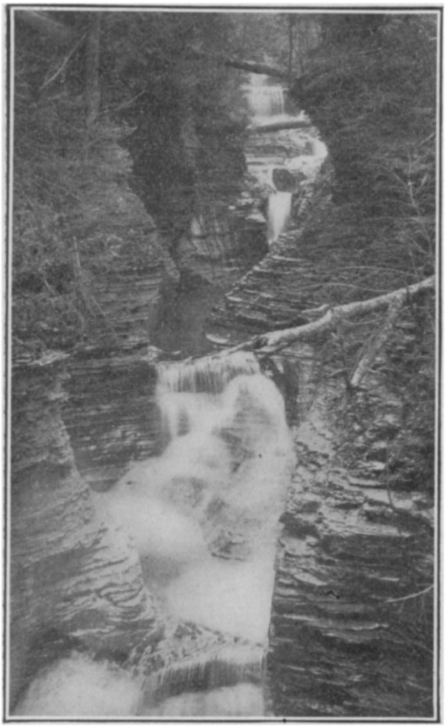


FIG. 5.—WATKINS GLEN, A POSTGLACIAL GORGE WHICH THE STREAM IS NOW RAPIDLY DEEPENING AS IT DESCENDS THE STEEPENED SLOPE OF THE SENECA VALLEY IN A SUCCESSION OF LEAPS.

Near the level where this change in slope occurs there have been two prominent causes for an unusual depth of drift. One of the lateral moraines of the Cayuga and Seneca Valley ice-tongues extends at about this level; and at a still later stage, when the retreating ice-sheet stretched across these lake valleys, forming a great ice-dam, delta terraces of gravel and sand were built at the mouth of each of the streams in the temporary lake. These drift obstructions have decidedly modified the courses pursued by the streams below the edge of the hanging valleys. Therefore it happens that, although there are pronounced earlier gorges extending down the slope below the edge of all the hanging valleys, and sometimes forming distinctly-marked depressions in the main valley slope, the postglacial streams do not always follow them, or, if they do, in many instances follow them for only a part of the distance. This fact has a profound influence on the forms assumed by the gorges of this region.

EFFECT OF BURIED GORGES.—Where a postglacial stream coincides with a section of a buried gorge, it has had an easy task to perform, merely stripping away the glacial drift. Since the buried gorges are broader than the postglacial rock gorges the valleys cut in postglacial time are distinctly broader where they coincide with the older gorges than where a new gorge has been cut in the rock. Furthermore, the buried gorges were cut to a greater depth than has been possible in the brief postglacial time, and therefore those streams which coincide with the buried gorges in their lower ends have deeper valleys than those which occupy postglacial gorges in their lower ends.

This condition may be well illustrated by briefly considering two contrasted instances. One of these is lower Six Mile Creek, which enters the Cayuga Valley from the east at Ithaca. About one mile from the point where this stream emerges upon the Ithaca delta it is flowing in a narrow postglacial gorge cut in the northeast wall of the buried gorge. In this section a picturesque fall has been developed. The stream then enters the buried gorge, whose further course upstream is partly hidden by drift deposits. In consequence of the discovery of this buried gorge by the stream the valley abruptly broadens, and this condition continues to the point where the creek emerges upon the Ithaca delta. This broad lower valley is a rock-walled gorge, with precipitous sides, but with the rock bottom nowhere revealed. The postglacial stream has only partially removed the drift-filling of the earlier gorge.

Of exactly the opposite type is Buttermilk Creek, the next stream to the south on the same (east) side of Cayuga Valley. At about the 800-foot level—that is, at the edge of the hanging valley —the creek is turned by moraine and delta deposits entirely aside from its buried gorge section. Consequently it enters the Cayuga Valley over the rock wall of the main valley several hundred yards south of the buried gorge, whose course is plainly traceable by a deep sag in the hillside and by occasional outcroppings of the gorge walls above the moraine-filling. Because of this diversion of the creek, the postglacial work of lower Buttermilk has been entirely in the bed-rock; and below the 800-foot level the gorge is, therefore, entirely of postglacial origin. It is in striking contrast to lower Six Mile Creek; for its gorge is narrow, the rock is everywhere present in its bed, and the slope is so steep that the stream forms a succession of rapids and falls. For part of the distance the stream flows almost flush with the main valley wall, having been incompetent to wear down its bed sufficiently to form a deep gorge.

Between the extreme types of Six Mile and Buttermilk Creeks there are numerous gradations; and there are a number of gorges which are possibly due to a combination of early and postglacial gorge-cutting. Lower Fall Creek, lower Taughannock, and a number of smaller streams are in broad gorges, with rock bottoms. In these instances it has not been proved beyond question, as it has been in Six Mile Creek, that the earlier gorge is occupied by the postglacial stream, and future study may prove that this is not the case; but the great breadth of these gorges is otherwise difficult to explain.

In several cases streams of similar volume, in approximately the same kind of rock, and with about the same grade, are occupying gorges markedly different in width and depth. This may be illustrated by comparing two small stream gorges with that of Buttermilk. Lick Brook, south of Buttermilk, and Esty Glen, north of Ithaca, both on the east side of the valley, have cut more pronounced gorges than lower Buttermilk, which is unquestionably entirely postglacial. Yet Buttermilk has much greater volume of water than either of the others; the grade of Buttermilk Creek is as great as that of Esty Creek and nearly as great as Lick Brook; and the rock is not greatly different. I am at a loss to account for this discrepancy on any other hypothesis than that both the Lick and Esty streams are occupying their earlier gorges; and this explanation is further strengthened by the fact that the older gorges of Esty Glen Stream and Lick Brook have not been found. A similar explanation is offered to account for many other cases of broad, deep lower gorge sections. It cannot be considered established; but with further investigation, now in progress, the correctness of the hypothesis will doubtless be fully tested. If this hypothesis proves incorrect, some other explanation will need to be found for the very striking difference in the depth and width of gorges which at first sight seem to be entirely postglacial in age.

In still another way the buried gorges influence the valley-forms. Where the streams cross the moraine and delta deposits, near the point where the slope changes from that of the hanging valleys to that of the main valley walls, they have often been given an irregular course. In the down-cutting through the drift to the underlying rock this postglacial course oftentimes leads to a cross-sectioning of the buried valleys, which the postglacial streams usually cross diagonally. This is exceedingly well illustrated in middle Six Mile Creek (Figs. 6, 7 and 9) above its lower course in the buried valley described above. Three times the creek crosses its buried gorge, each time entering it through one wall and leaving it across the opposite wall. In each case the valley-form changes abruptly as the stream enters and leaves the buried gorge. The postglacial section, cut in the buried gorge wall, is always narrow, with rock walls and rock bottom, over which the stream flows with rapids, or falls, or both. But in emerging into the buried gorges the valley abruptly broadens, rock is absent from the stream-bed, and on each side there is a section where rock is entirely absent from the valley sides. In these broad sections the stream meanders, forming terraces in the drift. Such broad sections are locally known as "amphitheatres." They make excellent sites for ponds, the outlet gorges being excellent dam sites (Fig. 7), and the breadth and gentle bottom slope of the "amphitheatres" being well suited for the

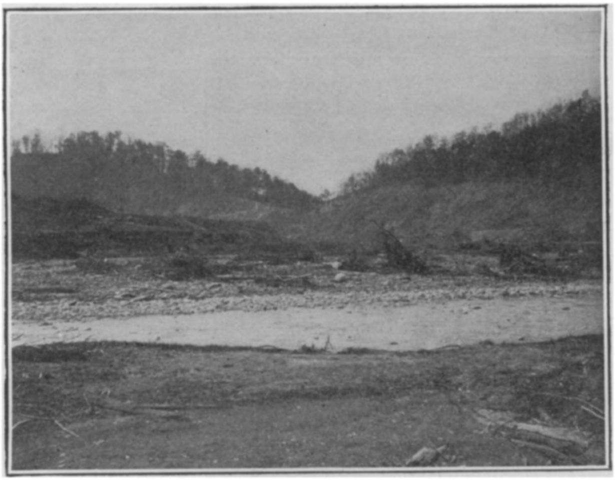


FIG. 6.—AN "AMPHITHEATRE" IN SIX MILE CREEK, LOOKING DOWN STREAM TOWARD THE DAM SITE (FIG. 7), WHICH IS SITUATED AT THE LOWEST POINT IN THE SKY LINE. THIS AMPHITHEATRE IS NOW FLOODED BY MEANS OF A DAM IN THE POSTGLACIAL GORGE (FIG. 7).

existence of ponds. Two of the "amphitheatres" of Six Mile Creek have been utilized for this purpose.

Other streams show the same condition. One of the best instances is that forming the site for the pond, called Beebe Lake, which contains the water supply for Cornell University and supplies the power for lighting the University and for its hydraulic laboratory. This is in Fall Creek, which forms the northern boundary of the Campus. Just above Forest Home, about one mile east of the University, the creek is in the older gorge, having up to this point a moderate grade in the hanging valley. At Forest Home the creek turns northward, having been deflected by a morainic spur; and, on cutting down through the moraine, it has encountered the rock of the northern wall of the buried gorge. In this a narrow postglacial gorge has been cut, with several rapids and falls. In the course of a few hundred yards the stream turns and reenters the buried gorge, which it crosses diagonally, entering the rock of the south wall at a distance of about a quarter of a mile from the point where it entered the buried gorge. Here it cuts another postglacial gorge with a series of very beautiful falls, much of whose beauty still remains, notwithstanding the building of a dam and the construction of a hydraulic laboratory in the gorge.

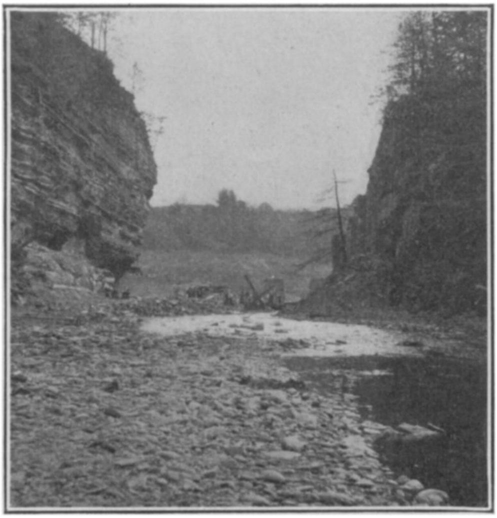


FIG. 7.—POSTGLACIAL GORGE IN SIX MILE CREEK, BELOW AN AMPHITHEATRE (FIG. 6). THIS IS NOW OCCUPIED BY A DAM AND A POND FILLS THE AMPHITHEATRE ABOVE.

These descriptions may be considered typical of conditions which are very common in the tributaries of Cayuga and Seneca Valleys. In this way scores of narrowing and broadening sections of the gorge valleys are explained.

EFFECT OF STRATA.—Being horizontal, the effects of differences in the strata on the gorge-form and waterfall outline are all of one general nature. On the gorge-walls the variations in texture cause a nearly horizontal banding, due to differences in resistance to weathering by the various strata. The effect varies greatly (Figs. 2, 3 and 5) according to the thickness of the various strata, the differences in durability of the successive layers, and the frequency of occurrence of hard layers. Every gorge shows some effect of this influence in the minor details of gorge-form; and sometimes it is very pronounced, especially where there are fairly thick layers of unusual hardness. In such cases there is sometimes an overhanging of portions of the gorge-wall where either undercutting by the stream or weathering out of weak strata has occurred beneath hard layers. These differences in rock strata are, however, nowhere great enough to give to the gorge-walls a distinctly terraced form.

The resistance of durable layers to the down-cutting of the streams is the cause for most of the rapids and falls of this region; but there are many differences among the falls, as a result of the varying conditions under which the strata occur. The differences in influence of strata may best be illustrated by means of a few type cases.

Only one of the strata of this section, the Tully limestone, is thick and massive enough to cause high falls over a single layer. Wherever the water flows over this layer, even in small streams, there is a pronounced fall, which, in all respects but size, closely resembles Niagara. The undermining of this limestone by removal of the underlying weak shale leaves it overhanging; a pothole is bored out at the base of the fall; and, by the falling of undermined blocks of the horizontal limestone, the fall gradually retreats upstream.

On a much smaller scale a similar condition is introduced by scores of thin sandstone strata. Usually, in such cases, only a low fall is caused, or perhaps no more than a rapid. Where the hard strata are near together the combined effect of several produces a step-fall (Figs. 2 and 3), which may attain considerable height if there are enough hard layers. Such a fall seems inclined, when viewed as a whole, but actually consists of a series of step-falls, each set a little back of the next one below. The inclined step-falls, well illustrated by Buttermilk Fall, are very often found where the postglacial stream has been precipitated down the steep face of the main valley wall into which time has not yet permitted the cutting of a deep gorge. On account of the exceedingly great variety in thickness, number, and spacing of the hard layers there is a great variety in the form of the falls, as may be inferred from the accompanying pictures.

EFFECT OF JOINT PLANES.—The details of gorge and waterfall form are profoundly influenced by the joint planes, by the aid of which the rock cleaves readily along the nearly vertical planes, which meet at almost right angles. This causes a rectangular buttressing of the gorge outline as one of the most characteristic features of the gorge-wall form (Fig. 8). The presence of several joint planes close together often permits the formation of a narrow chasm; and a combination of two such sets, at right angles, at times isolates a portion of the gorge-wall, leaving it standing as a column. The falling away of fragments along the joint planes leaves many smooth faces on the gorge-walls; and the formation of talus slopes at the bases of the cliffs, as well as the widening of the gorges, is greatly facilitated by the influence of the joint planes. Fresh scars caused by the recent falls of fragments weathered loose along joint planes may be seen each spring in most of the gorges.

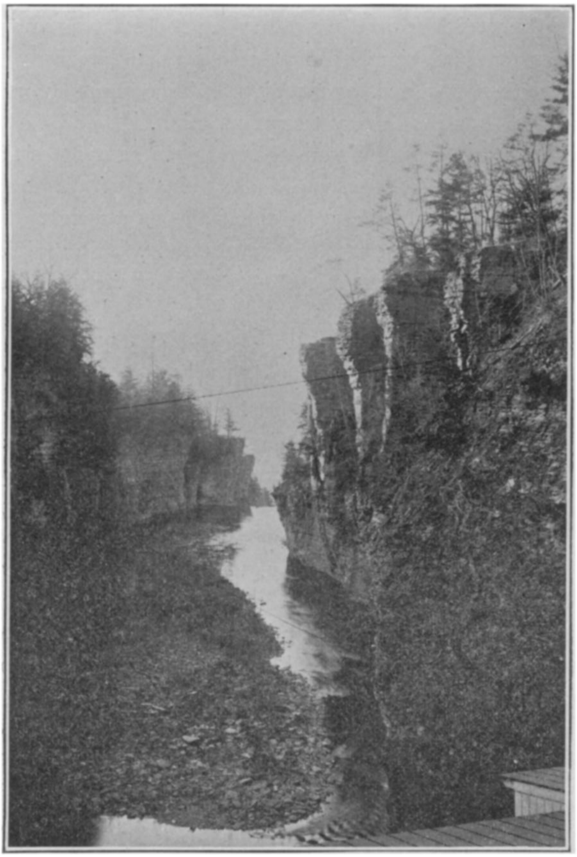


FIG. 8.—BUTTRESSES ON WALL OF FALL CREEK GORGE ITHACA, N. Y., DUE TO THE INFLUENCE OF JOINT PLANES.

The streams are often deflected by joint planes, sometimes occupying the space between two joints for a long distance, then, perhaps, turning at right angles to follow the other set for a distance. The presence of these joints greatly facilitates the stream work of valley-deepening.

Even more marked is the influence of joints on the form of the waterfalls. They guide the water in its course, often causing angular outlines in the waterfall (Fig. 9); and, by causing the rock to cleave, they sometimes give to the fall a vertical form where otherwise the stream would have an inclined slope. This is exceedingly well illustrated in the extreme case of Taughannock, the highest waterfall in the State, which has a vertical fall of 190 feet. There is no hard layer at the crest of Taughannock, but the fall occurs at a part of the gorge where both sets of joint planes are exceedingly well developed. At intervals varying from a few inches to several feet the joint planes cut the rock into vertical sheets, in some cases extending from the top to the bottom of the gorge. Frost and weather cause the rock to cleave along these planes so frequently that the face is left vertical. The very outline of the waterfall crest is determined by the joints. At present (Fig. 10) the outline of the crest is a re-entrant angle, due to the meeting of two joint planes; a few years ago (Fig. 10) the crest of the fall protruded to the opposite angle of the rhomb formed by two other parallel joint planes. The fall of the rhombic (almost cubical) block enclosed by the joint planes has caused a decided change in the outline of the

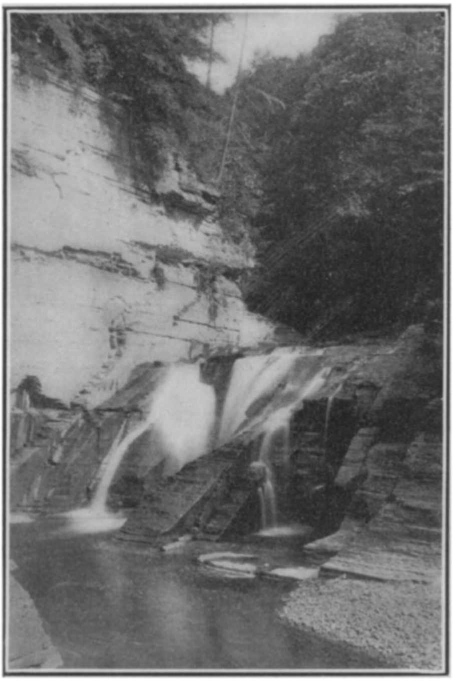
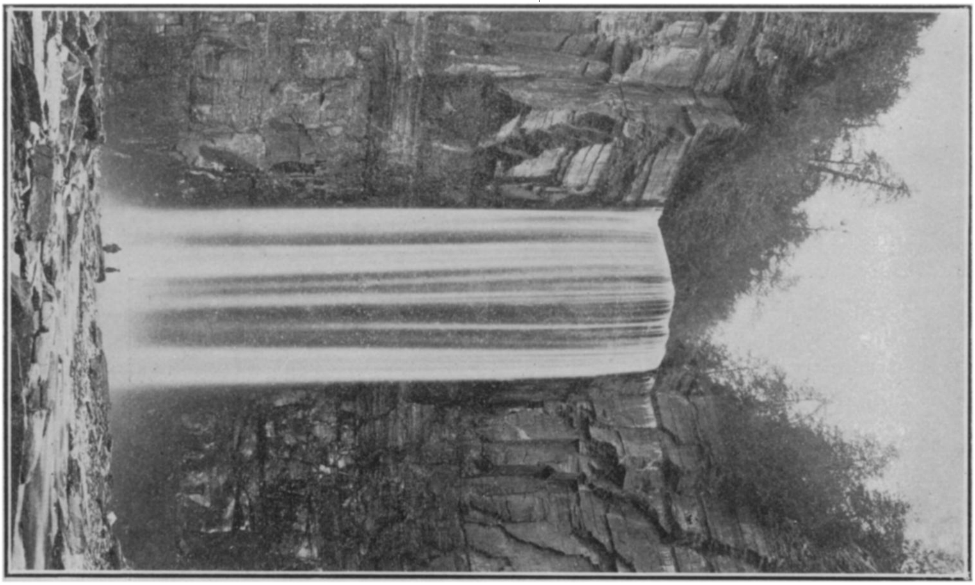
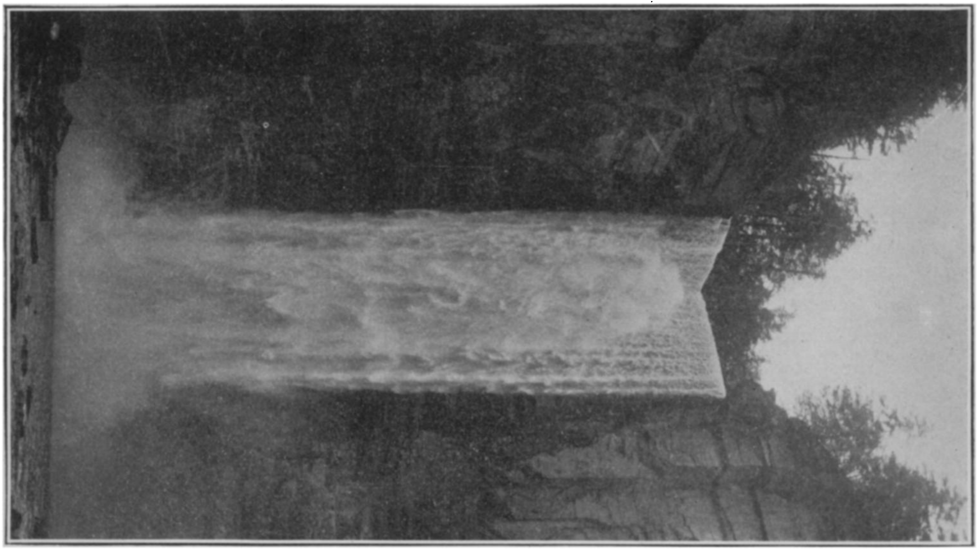


FIG. 9.—GREEN TREE FALL, SIX MILE CREEK, NEAR ITHACA, N. Y., SHOWING INFLUENCE OF JOINT PLANES ON WATERFALL FORM. THIS FALL IS AT THE POINT WHERE THE CREEK EMERGES FROM A POSTGLACIAL GORGE INTO ITS BURIED GORGE AT THE AMPHITHEATRE (FIG. 6). THIS IS IN THE NORTH WALL OF THE BURIED GORGE; FIGURE 7 IS IN THE SOUTH WALL.



TAUGHANNOCK—OLD OUTLINE.
FIG 10.—TAUGHANNOCK FALL, NORTH OF ITHACA, N. Y., ON WEST SIDE OF CAYUGA LAKE.



TAUGHANNOCK FALL—NEW OUTLINE.
DUE TO RECESSION BY FALLING AWAY OF A JOINT PLANE BLOCK.

fall. Almost every waterfall of good size is influenced either slightly or profoundly by the joint planes.

INFLUENCE OF THE GORGES AND FALLS.—In many ways these gorges have influence on life. They are usually a wilderness in the midst of a farming region. Therefore their flora and fauna are different from that of the surrounding land; and this difference is increased by the dampness and shade of the narrow gorges. To show the exact amount of difference in life is a task for the ecologist.

These strips of wilderness cut up single farms and interfere with communication between neighbouring farms. They deflect roads or else cause the construction of expensive bridges. For example, until four or five years ago there was no road bridge across the Fall Creek gorge, although it forms the northern boundary of the Cornell Campus, and the University buildings extend to the very edge of the gorge. The building of a bridge quickly opened up the region on the opposite side of the gorge, and in five years it has become one of the important residential sections of Ithaca.

The gorges also influence the railroads. Thus, the Delaware, Lackawanna and Western Railway enters Ithaca by means of a switchback, causing an increase in distance and consequent delay, and introducing a very heavy grade, down the steepened valley slope, to avoid the expensive construction necessary to enter by a more direct course—along the Six Mile Creek valley, into which enter many small tributaries in deep gorges. The Lehigh Valley Railway decided against the Ithaca route for its main line, building a double-track road, at heavy expense, through the Seneca Valley, at the level of the steepened slope, above the upper ends of the gorges. To use the Ithaca route it was necessary either to descend to Ithaca by steep grade and ascend by even steeper grade, along the route followed by the present Ithaca branch, or else to establish a grade on the hillside and bridge a number of deep gorges.

As already stated, the amphitheatres are natural sites for storage reservoirs, and are used for this purpose in a number of instances, partly for water supply, partly for power. The Ithaca water supply, as well as that of Cornell University, is at present obtained from the creeks, dammed at the lower ends of amphitheatres. The many falls give ample opportunity for power wherever the water supply is sufficient. Unfortunately, in most cases the water supply is limited and variable, and the variability is being steadily increased by the continued removal of the woodlands, thus making this source of power even less useful than formerly. The creeks, at times roaring torrents, are greatly lowered in summer by drought, and in winter by frost; and industries requiring steady power are in many cases required to supplement the water-power by steam. Yet there are numerous small industries, such as grist mills, which make use of the power. Ithaca owes its early growth in part to the water-power available in the neighbouring creeks.

The use of the creeks for this purpose is diminishing, and at present the most varied and extensive use of water-power in this neighbourhood is that made by Cornell University, which obtains from Fall Creek not only its water supply, but also power for developing electricity for lighting its buildings, power for the engineering shops, and water for its hydraulic laboratory.

Not the least important influence of the gorges and waterfalls is the influence of their beauty on those who know them. This influence defies attempt at quantitative statement. It has a direct money value in the case of Watkins and Havana Glens, where there are gate receipts for entrance; but the value to the many tourists cannot be estimated. The reputation of Watkins Glen has led to an effort, maintained for several years, but as yet unsuccessful, to have it made a State Park.

Even more important than this, however, is the influence of the beautiful scenery upon the throngs of students who attend Cornell University. Some, it is true, never see any of the natural scenery excepting that which is forced upon them in crossing the gorges as they pass to and fro from their work; but the majority explore the gorges near by, and many extend their explorations far and wide. The influence of beautiful surroundings on character is unquestionably great, and the thousands who study at Cornell University have this influence thrust upon them.